

# POLLENS OF *NOTHOFAGUS* BLUME FROM TERTIARY DEPOSITS IN AUSTRALIA.

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(Communicated by Dr. Ida A. Brown.)

(Plates i-ii; eleven Text-figures.)

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## INTRODUCTION.

In view of the general recognition that fossil pollens, when studied in conjunction with pollens of living species, provide reliable information regarding the composition and distribution of past floras, it is surprising that in Australia this field has, hitherto, been unexplored.

Tertiary palaeobotanists in this country have largely restricted themselves to the macroscopical study of leaf impressions many of which are of a fragmentary and doubtful nature. Pollen grains are generally conceded to be less variable units than leaves, so that a study of fossil pollens should both widen our conception of Australian floras and throw light on the origins of endemic species. For these reasons an investigation covering the pollen content of Australian Tertiary and Recent deposits has been planned.

Practically no literature exists that deals specifically with pollens of living Australian plants; and, although Cranwell's (1939, 1940, 1942) excellent memoirs on New Zealand pollens are extremely helpful in the elucidation of species common to both countries, the identification of fossil species will, necessarily, be slow, and some considerable time must elapse before any generalizations can be made. In the meantime, it is proposed to publish at intervals illustrated botanical descriptions whereby the genera present in the various geological deposits may be recognized, also the bases upon which these identifications have been made.

Since pollens of *Nothofagus* spp. are amongst the most conspicuous that have been isolated, both numerically and specifically, they have been selected as the subject of this introductory paper. They occur more or less abundantly in the majority of lignites, clays and mudstones that have been examined at present. Moreover, their characteristics are so distinctive that no question of generic identity arises and the unmodified name *Nothofagus* can be used with confidence. Several clearly defined kinds are preserved. These are regarded as pollens of individual fossil species, but instead of providing them with specific names, they will subsequently be referred to as *Nothofagus* sp. with a different letter of the alphabet to designate each.

Nine species of *Nothofagus* have already been distinguished in Australian Tertiary rocks by variation in leaf-form. Nevertheless, until organic connection between recognizable leaves and male flowers with pollen *in situ* is established, identification of the pollen types with any of these species will be impossible.

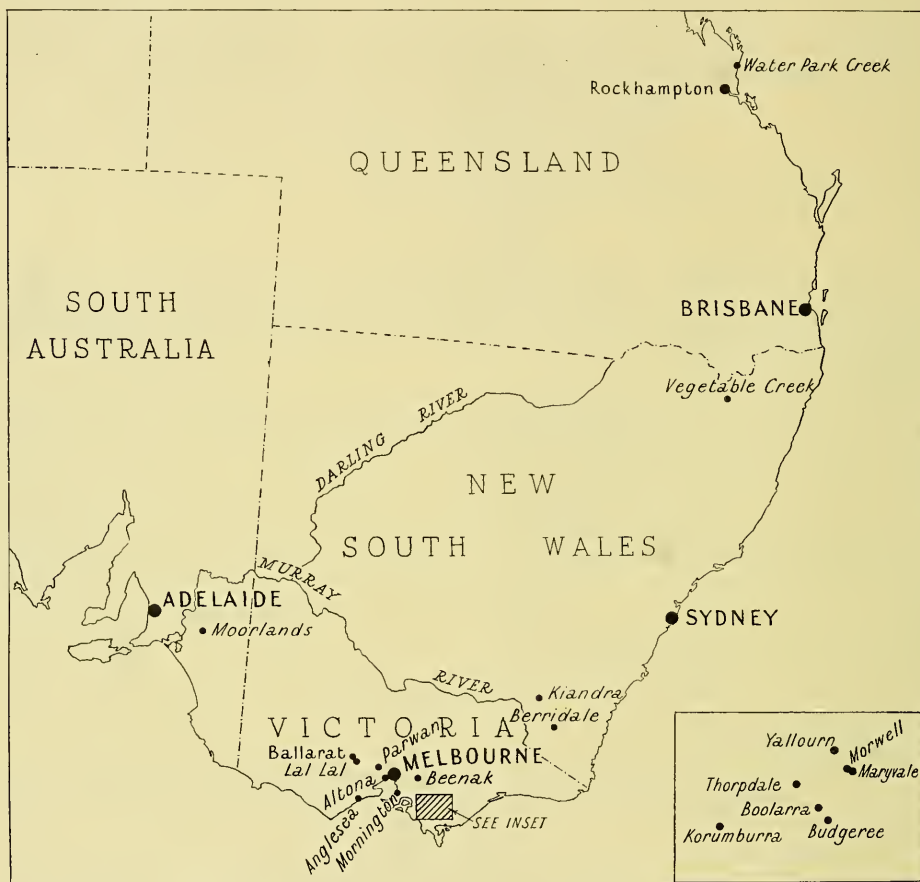
The distribution of the fossil species will be indicated; but it has not been possible to consider this at all exhaustively. It must remain for future work, also, to trace the vertical range of individual types through any one deposit.

## SOURCE AND AGE OF SAMPLES INVESTIGATED.

### *Lignites and Ligneous Clays.*

The extensive seams of brown coal and associated ligneous clays that occur in southern Victoria and south-eastern South Australia have provided the major source of the fossil beech pollens to be described below. These deposits reach a maximum thickness, probably exceeding 1,000 feet, in the Latrobe Valley in south-eastern Victoria where

at Yallourn and Morwell they are being worked by the State Electricity Commission. Boring operations at present in progress have, through the courtesy of the staff of the Commission, facilitated the examination of samples from specified levels. The following localities will be referred to in connection with the distribution of fossil pollens (Text-fig. 1).



Text-fig. 1.—Map of south-eastern Australia showing location of deposits in which *Nothofagus* spp. occur. (Prepared by the Geological Survey of Victoria.)

(a) *Victoria.*

Altona. Lignite from Melbourne and Altona Colliery Company's mine at 362 feet level No. 9 dip. G.S.V.\* specimen.

Parwan. G.S.V. Bores 9 and 10, about 30 miles west of Melbourne.

Lal Lal. Samples from dump of an abandoned mine 15 miles south-east of Ballarat.

Beenaak. (Kebble, 1925.) Lignite from allotment 68c, Parish of Beenaak, about 6½ miles from Yarra Junction. M.U.G.D.† specimen.

Boolarra. Lignite from Mirboo Colliery shaft at the 162 feet level, 3 miles north-east of Boolarra. G.S.V. specimen.

Budgeree. Lignite from shaft in allotment 6D, Parish of Budgeree. G.S.V. specimen.

Korumburra south of Parish of Leongatha, ligneous clay from Bore at 350 feet. G.S.V. specimen.

Maryvale. Ligneous clay from Bore 155 at 552 and 760–761 feet.

\* G.S.V., Geological Survey of Victoria.

† M.U.G.D., Melbourne University Geological Department.

Maryvale. Lignite from Bore 169, 392-402 feet.

Yallourn. Lignite from open cut, S.E.C. samples 1-6 taken at depths from top of coal of 11, 32, 62, 92, 120, 150 feet respectively.

Yallourn. Ligneous clay from floor of open cut. M.U.G.D. specimen collected by Professor E. S. Hills.

(b) *South Australia.*

In this State the chief brown coal deposits are situated near Moorlands, a railway station on the Pinaroo line about 87 miles south-east of Adelaide (Mawson and Chapman, 1922). Preparations were made from a mixed coal-sample obtained from the Mines Department of South Australia.

(c) *New South Wales.*

Samples from the Southern Tableland were provided by Dr. J. A. Dulhunty from his coal collection as follows:

Kiandra, New Chum Hill (Sussmilch, 1937, p. xii). C.S. 104, ligneous clay, 30 feet below the base of the basalt. C.S. 87, low grade coal, 70 feet below the basalt. C.S. 103, soft ligneous shale 135 feet below the basalt.

Berridale, Wullwye Creek, C.S. 89, ligneous clay over 100 feet below the basalt.

*Sandstones, Mudstones, etc.*

Anglesea (Singleton, 1941, p. 24). Black carbonaceous sandstone from cliffs 1 mile north-east of mouth of Anglesea River, Parish of Jan Juc, Victoria.

Balcombe Bay (Singleton, 1941, p. 26). Mudstone containing leaf-remains from coastal cliffs about 2 miles south of Mornington, Victoria.

Vegetable Creek (Emmaville) (Sussmilch, 1937, p. ix). Mudstone from deep leads in the New England Tableland, northern New South Wales. M.U.G.D. Fossil Collection, Nos. 242, 501.

Unanimity of opinion regarding the detailed stratigraphy of the Tertiary rocks of south-eastern Australia has not yet been reached. Somewhat different views are held by the chief workers. Singleton (1941, p. 49) suggests Oligocene as the probable age of the brown coal deposits, while Crespin (1943) places them as Lower to Upper-Middle-Miocene. Singleton also tentatively assigns the Anglesea sandstones and the leads of the Vegetable Creek to the Oligocene Epoch.

In view of this position, it appears that Oligocene-Miocene is the closest approximation to the age of the fossil *Nothofagus* pollens possible at present.

TREATMENT OF MATERIAL.

The method that has proved most satisfactory for the making of pollen preparations from Tertiary lignites is the chlorination-acetolysis method devised and perfected by Erdtman (1943, p. 34). The ease, however, with which the extraneous material is removed from individual samples has been found to vary considerably with the nature of the coal itself. Usually it is necessary to give the acetolysed residue one or even several washings with warm caustic potash of strengths ranging from 0.5-10% according to its resistance to clearing.

After a preliminary treatment with hydrofluoric acid the same method has been employed in the examination of sandstones, mudstones and ligneous clays. When, as sometimes happens, a lignite contains a certain amount of silica, more satisfactory preparations are obtained if treatment with hydrofluoric acid precedes acetolysis.

Glycerine-jelly has been employed exclusively as a mounting medium, either uncoloured or coloured lightly with basic fuchsin.

INVESTIGATIONS ON *NOTHOFAGUS* POLLENS.

*Nothofagus* pollen was first described in 1929 by von Post (1929), who based his description on three living South American species.

In 1933 Auer recorded and figured *Nothofagus* pollens from peats of Tierra del Fuego, without, however, giving detailed information regarding their salient features. Cranwell and von Post (1936) recognized the distinction between *N. Menziesii* pollen



and the pollens of the other four New Zealand species and recorded the presence of both types in post-Pleistocene peats.

It remained for Cranwell (1939) to describe in detail the pollens of most of the living species. By means of these descriptions the identification of southern beech pollens in peats and the determination of the affinity of older types are now possible. The separation of *Nothofagus* species into two pollen-groups, named by Cranwell the *Menziesii* and *fusca* groups respectively, is an interesting and important basis for work on fossil species. Cranwell found that most of the New Zealand and South American species have pollen of the *fusca* type whereas two of the three Australian species have pollen of the *Menziesii* type. Records of *N. Menziesii* and *N. fusca* pollens from various New Zealand peats were made. In addition, the *fusca* type was recorded from a Tertiary deposit at Kaikorai, and a possible "intermediate type" from Whangamarino was briefly described.

A description of the pollen of the Tasmanian species, *N. Gunnii* (Hook.) Oerst was not included in Cranwell's paper. In a separate note\* I have shown this pollen to be of the *fusca* type.

#### IDENTIFICATION OF NOTHOFAGUS POLLENS.

As the result of comparisons made between the pollens of wind-pollinated members of the Fagaceae, namely, *Quercus*, *Fagus* and *Nothofagus*, Cranwell (1939) was able to arrive at a "basic description" to cover all three types. This is quoted as follows: "Grains rather large, usually about .040 mm. more or less spherical to very flattened; furrows wherever recognizable directed meridionally, the pores where present being arranged in an equatorial circle. Exine fairly thick, always warty-granular."

*Fagus* and *Quercus* pollens have three furrows; *Nothofagus* pollens on the other hand have several, which are usually coincident with the pores. *Nothofagus* pollens of Cranwell's *Menziesii* group (Plate i, fig. 1) have diameters of from 40–60 $\mu$ , a thin exine, and in place of functional pores for the emergence of the pollen-tubes, fissure-points around the equator where rupturing of the grains takes place. *Nothofagus* pollens of the *fusca* type (Plate i, fig. 16) are usually less than 40 $\mu$  and the exine is thick, especially around the pores.

The fossil types all conform to the basic description given above. Most of them have well-defined meridionally placed pores or furrows which apparently were functional, and prominent sculpture. The characters that have been relied upon to distinguish the various forms have been pore-number, thickness of exine, type of sculpture, and, less frequently, size of grain. Wherever possible the pore-number and average size have been determined from a large number of individual counts, in some instances amounting to several hundreds. In no case has a value used been derived from less than 50 grains.

The decision to allow a wide size-range within a type is supported by the existence of this feature in the pollen of some of the living species, for example, *N. Menziesii* in which Cranwell noted a difference of 20 $\mu$  between the smallest and largest grains.

Variation in the strength of the sculpture also occurs. This has raised difficulties in the matching of types in preparations from different localities. A broad view of these divergencies has been adopted. It is recognized that later, when individual deposits are worked at regular vertical intervals, further subdivision of some of the fossil species may be necessary. This is particularly so, for instance, with the Moorlands lignite, in which, judging from the mixed sample examined, some of the beech pollen-types are difficult to match exactly with those from more eastern localities.

In connection with the occurrence of such variations as quality of sculpture and average size within the fossil species described in this paper, it must be borne in mind that evidence of hybridization between members of the *fusca* pollen group has been established for New Zealand species (Anonymous, 1944) and that this has an effect on certain characters of the pollen of the hybrid (Cranwell, 1939). Since crossing is occurring naturally at the present time, there is reason to think that it may have taken

\* "Note on the Pollen of *Nothofagus Gunnii* (Hook.) Oerst." To be published in *Proc. Roy. Soc. Vict.*, 58 (1), 1946, p. 1.

place during the past history of the genus and that some of the difficulties experienced in placing, systematically, what appear to be atypical pollens may be due to this cause.

#### DESCRIPTIONS OF FOSSIL POLLENS.

*Nothofagus* sp. *a*. (Plate i, figs. 5-7. Text-fig. 2. Table 1).

*General remarks*.—Conforms closely to the description of *N. Menziesii* given by Cranwell (1939, p. 182) and can be distinguished readily from other *Nothofagus* pollens in the samples examined on account of its size, delicate exine, and the absence of either furrows or pores.

*Grain*.—Large, diameter 40–60 $\mu$  with an average of 52 $\mu$ . When unruptured, circular or slightly angular with the positions of the fissure-points faintly indicated around the equator. The majority of grains are, however, much flattened and partially or completely ruptured, when their outline becomes strongly angular. The fissures range from 6–9, the commonest number being 7, and gape widely.

*Exine*.—Less than 1 $\mu$  and completely covered with small sharply-pointed papillae.

*Affinity*.—A close affinity exists between *N. sp. a*. and pollens of the *Menziesii* type; these pollens, owing to their strikingly uniform character, are extremely difficult to distinguish from one another. All have 7 as the predominant number of fissure-points, and should they occur together in a pollen mixture, the sculpture is hardly sufficiently distinctive to allow of confident specific identification.

Acetolysed pollens of *N. Menziesii* Oerst, *N. Moorei* (F. Muell.) Maiden and *N. Cunninghami* (Hook.) Oerst\* have been carefully studied in conjunction with those of *N. sp. a*., and so that direct comparisons can be made, photographic illustrations of them are provided in Plate i, figs. 1–4.

Although the fossil grain has a slightly greater diameter and wider size-range, it is very close to the pollen of *N. Moorei*, the papillae in both tending to be slightly less crowded than in either *N. Menziesii* or *N. Cunninghami*. In this connection it is interesting to note that von Ettingshausen (1888, p. 34) observed a remarkable resemblance between the leaves of his species, *Fagus Wilkinsoni*, *Nothofagus Wilkinsoni* (Ett.) Paterson (1934) and those of *N. Moorei*, and went so far as to say: "The supposition that there is a genetic connection between the two species, cannot therefore be wrong."

In the absence of macroscopical remains in intimate association with *N. sp. a*., its identification with any one of the recognized species of *Nothofagus*, either living or extinct, would be unsound; but the evidence is clear that pollen of the *Menziesii* type had evolved by the Miocene Epoch, and that the species producing it was fairly widely distributed.

#### *Distribution*.

*Lignites*: Beenak.

*Ligneous Clay*: Maryvale Bore 155, 552 feet level; south of Korumburra Bore 5 at 570 feet.

*Ligneous Shale*: Kiandra C.S. 103.

*Mudstones*: Balcombe Bay, Vegetable Creek.

TABLE 1.

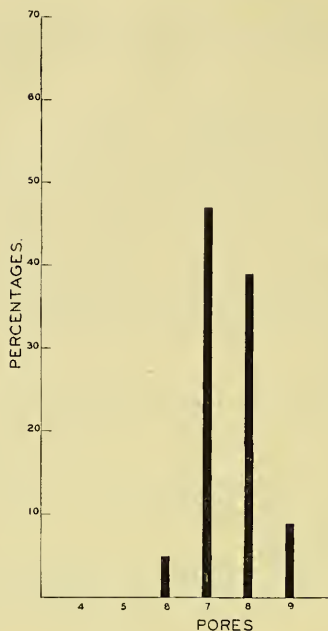
Locality.	Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.
Maryvale Bore 155, 552 feet ..	42.5–63.8 $\mu$	53 $\mu$	6–9	49% 7
Vegetable Creek .. ..	40.0–63.8 $\mu$	52 $\mu$	6–9	49% 7

*Nothofagus* sp. *b*. (Plate i, figs. 8–13. Text-fig. 3. Table 2).

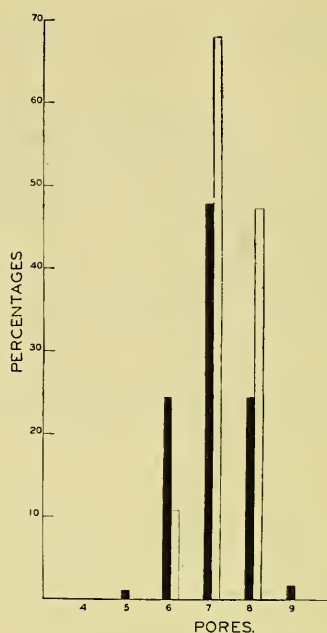
*General remarks*.—A pollen that conforms to the general description of *N. fusca* (Cranwell, 1939, p. 185).

*Grain*.—Bi-convex, typically circular in polar view. Size-range 21.5–40.0 $\mu$ , the collective average from all localities being 30 $\mu$ . Pores 5–9, mainly 6 and 7, the majority 7; sunken about 2.5 $\mu$ .

\* Pollen of *N. obliqua* (Mirb.) Blume, the South American member of this group, has not been available for comparison.



Text-fig. 2.



Text-fig. 3.

Text-fig. 2.—Pore-frequencies in *N. sp. a.* from Maryvale. Bore 155 at 552 feet.

Text-fig. 3.—Pore-frequencies in *N. sp. b.* □ Maryvale. Bore 155 at 762 feet; ■ Vegetable Creek.

*Exine*.—Firm, about  $1.3\mu$  thick between the pores,  $2.0$ – $2.6\mu$  at the rims of the pores. Sculpture strong and clear, papillae very short and moderately close.

*Affinity*.—Characters such as the collar-like pore-rims and the type of sculpture place *N. sp. b.* unquestionably in the *fusca* group and completely demonstrate that the second of the two divergent pollen groups was also well established during Miocene times.

The existing species with which it is most natural that *N. sp. b.* should be compared is *N. Gunnii*, which alone of the living Australian species has pollen of the *fusca* type (Plate i, figs. 14, 15). Undoubtedly close agreement exists between these two pollens, their average sizes are practically identical and the fact that the majority of grains have 6 or 7 pores is noteworthy. The pore-maxima, however, are different. In *N. Gunnii* the majority of grains have 6 pores, whereas in *N. sp. b.* the maximum falls on 7. Moreover, the sculpture of the latter is stronger and the exine slightly thinner.

In view of the fact that the majority of New Zealand and South American beeches have pollen of the *fusca* type, it is tempting to speculate upon the connection between these and the Australian species with the same variety of pollen. Unfortunately, considerably more information is needed from peats and deep deposits in those countries, as well as in Australia, before this interesting evolutionary and phytogeographical problem will be solved.

#### *Distribution.*

*Lignites*: Moorlands, Beenak, Boolara, Thorpdale.

*Ligneous Clays*: Maryvale Bore 155 at 552 and 762 feet levels.

*Sandstones and Mudstones*: Anglesea, Balcombe Bay, Vegetable Creek.

TABLE 2.

Locality.	Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.
Anglesea .. .. .	$21.0$ – $34.6\mu$	$27.0\mu$	5–8	54.5% 7
Maryvale Bore 155, 762 feet	$26.6$ – $37.0\mu$	$30.6\mu$	6–8	68.0% 7
Moorlands .. .. .	$26.6$ – $40.0\mu$	$32.0\mu$	6–8	61.0% 7
Vegetable Creek .. .. .	$26.6$ – $40.0\mu$	$32.0\mu$	5–9	47.0% 7
Maryvale Bore 155, 552 feet	$26.6$ – $40.0\mu$	$33.0\mu$	5–8	57.5% 7



*Nothofagus* sp. c. (Plate i, figs. 17, 18. Text-fig. 4. Table 3).

*General remarks.*—A clearly defined extinct pollen of the *fusca* type, from present experience, usually preserved in comparatively small numbers. Most abundant in samples from Lal Lal and Vegetable Creek.

*Grain.*—Delicate, flattened, frequently folded or wrinkled, circular in polar view. Large, size-range  $26.6\text{--}64.0\mu$ , average approximately  $40\mu$ . Pores 5–8, very rarely 4, mainly 6 and 7; sunken about  $3\mu$ .

*Exine.*—Delicate, about  $1\mu$ ,  $3\text{--}4\mu$  around the pores. Sculpture fine and often inconspicuous.

*Affinity.*—A further clear example of the *fusca* pollen-group. Not to be confused with either *N. sp. b.* or other pollens of this group on account of the delicate exine and contrastingly conspicuous pore-rims.

*Distribution.*

*Lignites:* Moorlands, Parwan Bores 9 and 10, Lal Lal, Beenak, Boolara, Thorpdale.

*Ligneous Clays:* Maryvale Bore 155 at 552 and 760 feet levels, Berridale C.S. 89.

*Sandstones and Shales:* Anglesea, Balcombe Bay, Vegetable Creek.

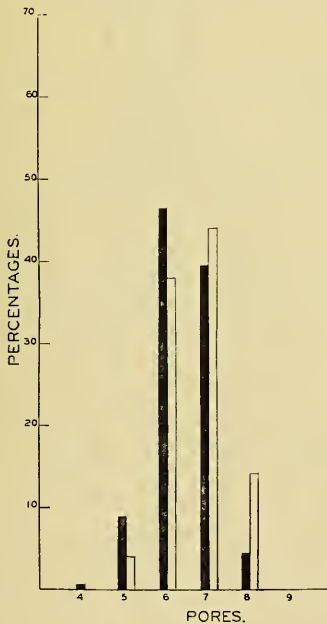
TABLE 3.

Locality.	Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.
Lal Lal .. ..	$26.6\text{--}53.0\mu$	$37.5\mu$	4–8	46.5% 6
Vegetable Creek ..	$29.5\text{--}64.0\mu$	$45.0\mu$	5–8	44.0% 7

*Nothofagus* sp. d. (Plate i, figs. 19–21. Text-fig. 5. Table 4).

*General remarks.*—A widespread, characteristically small, echinate pollen.

*Grain.*—Bi-convex almost circular in polar views. Size-range  $18.6\text{--}35.0\mu$ , the average size varying fairly considerably with the locality (Table 4). Pores 5–8, mainly 6 and 7, sunken approximately  $2.5\mu$ .



Text-fig. 4.



Text-fig. 5.

Text-fig. 4.—Pore-frequencies in *N. sp. c.*  Vegetable Creek;  Lal Lal.

Text-fig. 5.—Pore-frequencies in *N. sp. d.*  Parwan Bores 9 and 10;  Yallourn open cut, 62–150 feet.

*Exine*.—Firm, 1–2 $\mu$  conspicuously thickened around the pores. Sculpture prominent in proportion to the size of the grain, in the form of clear echinate papillae about 1.0–1.5 $\mu$  in length and from approximately 0.5–2.0 $\mu$  across the base.

*Affinity*.—The thickening of the exine around the pores at once suggests a resemblance to the pollen of the *N. fusca* type, but the sculpture is markedly different and the sharply pointed papillae recall those of the *N. Menziesii* pollen group. *N. sp. d.* appears to be a clear example of an intermediate type.

*Distribution*.

*Lignites*: Moorlands, Parwan Bores 9 and 10, Beenak, Yallourn open cut 62–150 feet, Maryvale Bore 174 at 40–50 feet, Budgerie, Thorpdale.

*Ligneous Clay*: Maryvale Bore 155 at 552 feet.

*Sandstones and Mudstones*: Anglesea, Balcombe Bay, Vegetable Creek.

TABLE 4.

Locality.	Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.
Maryvale Bore 174, 40–50 feet	21.0–26.6 $\mu$	24.5 $\mu$	5–8	58% 6
Anglesea .. ..	21.0–26.0 $\mu$	24.5 $\mu$	5–8	50% 7
Maryvale Bore 169, 392 feet	21.0–29.0 $\mu$	25.0 $\mu$	6–8	62% 7
Yallourn open cut, 62–150 feet	18.6–32.0 $\mu$	26.6 $\mu$	5–7	65% 6
Balcombe Bay .. ..	24.0–29.0 $\mu$	27.0 $\mu$	6–8	68% 7
Moorlands .. ..	26.6–35.0 $\mu$	29.0 $\mu$	6–8	67% 7

The types that follow represent pollens of extinct species of *Nothofagus*, none of which can be directly associated with the present-day pollen groups. The fact that the pore-slits were clearly defined and opened without rupture of the grain separates them from the *Menziesii* group. By the uniform thickness of the exine they are removed from the *fusca* group.

*Nothofagus sp. e.* (Plate ii, figs. 22–25. Text-fig. 6. Table 5).

*General remarks*.—The most widespread and abundant beech pollen in the deposits examined.

*Grain*.—Strongly angular in polar view due to the deeply-sunken pores. Size-range 18.6–42.5 $\mu$  with an exceedingly variable average over a range of localities (Table 5). Pores 4–7, mainly 5 and 6, the majority 6, sunken 5–8 $\mu$ .

*Exine*.—Thin but firm, of uniform thickness, approximately 1 $\mu$ , forming definite though unthickened rims to the pore-slits. Sculpture fine, sometimes faint; papillae short and pointed, frequently less crowded and smaller towards the equator.

*Affinity*.—Appears to be indicated with *N. sp. f.* in which there is a general similarity of form. In samples such as those from Balcombe Bay where *N. sp. e.* is associated with *N. sp. h.* some difficulty may be experienced in assigning grains with identical pore numbers to one or other species. When, however, large numbers of grains are carefully examined, the chief specific difference, that is, the lower pore-maximum and pore-range of *N. sp. e.*, becomes clear.

*Distribution*.

*Lignites*: Moorlands, Parwan Bores 9 and 10, Altona, Beenak, Yallourn open cut 62–150 feet, Maryvale Bore 169, 392 feet, Boolara, Thorpdale.

TABLE 5.

Locality.	Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.
Maryvale Bore 169, 392 feet ..	21.0–29.0 $\mu$	24.0 $\mu$	4–7	58% 6
Yallourn clay .. ..	18.6–40.0 $\mu$	29.0 $\mu$	4–7	51% 5
Thorpdale .. ..	24.0–40.0 $\mu$	29.5 $\mu$	5–7	55% 6
Boolara .. ..	26.6–40.0 $\mu$	30.5 $\mu$	5–7	68% 6
Balcombe Bay .. ..	24.0–40.0 $\mu$	32.0 $\mu$	5–7	57% 6
Yallourn open cut S.4, 92 feet	21.0–42.5 $\mu$	33.0 $\mu$	4–7	48% 6



*Ligneous Clays*: Yallourn open cut S.4, 92 feet, Maryvale Bore 155, 552 feet, Kiandra C.S. 103, C.S. 104, Berridale, C.S. 89.

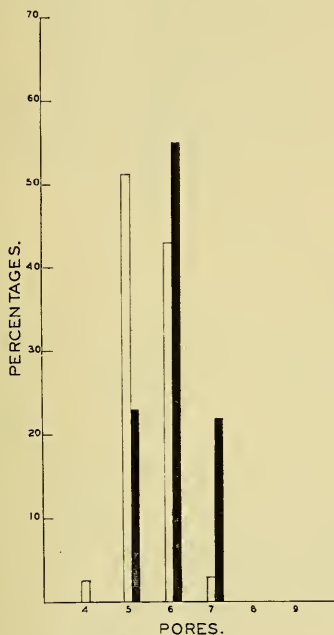
*Sandstones and Mudstones*: Anglesea, Balcombe Bay, Vegetable Creek.

*Nothofagus* sp. f. (Plate ii, figs. 26–29. Text-fig. 7. Table 6).

*General remarks*.—A uniform and widespread type. Present in smaller numbers than *N. sp. e.* with which it appears to be frequently associated.

*Grain*.—Bi-convex and prominently angular in polar view with deeply set pores. Size-range from 26–47 $\mu$  with an average from several localities of approximately 34 $\mu$ . Pores 4–7, mainly 5 and 6, sunken from 5–7.5 $\mu$ .

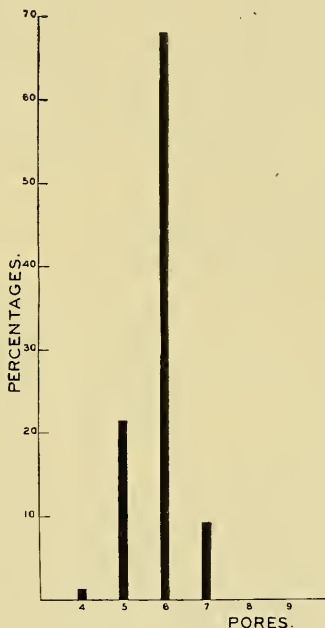
*Exine*.—About 2 $\mu$ , usually thinning slightly towards the well-defined rims of the pore-slits and frequently embayed between them. Papillae clear, short, sharply-pointed, becoming slightly smaller towards the equator of the grain, typically rather widely spaced at intervals of 1.5–2.5 $\mu$ .



Text-fig. 6.

Text-fig. 6.—Pore-frequencies in *N. sp. e.* □ Yallourn clay; ■ Thorpdale.

Text-fig. 7.—Pore-frequencies in *N. sp. f.* from Boolara.



Text-fig. 7.

*Affinity*.—In its low pore-number, firm exine, deeply sunken pores and angular character, *N. sp. f.* closely approaches *N. sp. e.* It is treated as a separate species on account of the consistently thicker exine, the more distantly placed papillae and the frequent embayment of the exine between the rims of the pore-slits.

#### *Distribution.*

*Lignites*: Moorlands, Altona, Yallourn S.4, 92 feet, Boolara, Budgeree.

*Ligneous Clay*: Maryvale Bore 155 at 552 feet.

*Sandstones, Mudstones*: Anglesea, Balcombe Bay, Vegetable Creek.

TABLE 6.

Locality.	Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.
Maryvale Bore 155, 552 feet	26.6–40.0 $\mu$	32.5 $\mu$	5–7	51% 6
Balcombe Bay .. ..	29.0–40.0 $\mu$	32.5 $\mu$	5–7	59% 6
Boolara .. ..	26.6–40.0 $\mu$	33.0 $\mu$	4–7	68% 6
Vegetable Creek .. ..	26.6–42.5 $\mu$	33.0 $\mu$	5–7	60% 6
Moorlands .. ..	31.0–47.0 $\mu$	40.0 $\mu$	4–7	55% 6

*Nothofagus* sp. *g.* (Plate ii, figs. 30-32. Text-fig. 8. Table 7).

*General remarks.*—One of the larger and rarer types, the limits of which are the least clearly defined. Present in sufficient numbers for critical analysis in preparations from only two localities, namely, Vegetable Creek and Beenak.

*Grain.*—Large, considerably flattened and strongly angular in polar view. Size-range 32.0-58.5 $\mu$ , the average being between 40-45 $\mu$  (Table 7). Pores 4-7, majority 5 and 6, sunken 8.0-10.5 $\mu$ .

*Exine.*—Delicate, approximately 1 $\mu$  or even less as in the examples from Vegetable Creek. Sculpture distinct, papillae fine, sharp, rather widely spaced at distances approximating to 2-3 $\mu$ .

*Affinity.*—This species is insufficiently known at present. All examples have been more or less fully expanded. On account of the delicate nature of the exine some difficulty was experienced in deciding whether the deep gaps, evident in every grain, represent fissures or widely open predetermined narrow-rimmed pore-slits related to functional pores. The latter view, adopted after careful examination of the Vegetable Creek form, has been confirmed by examples in preparations of lignite from Beenak. In these the exine is slightly thicker and the rims to the pore-slits more distinct.

In spite of the low pore-number, *N. sp. g.* approaches more closely than any of the other fossil species to pollens of the *Menziesii* group in general and to *N. sp. a.* in particular. It is possible that it may prove to be a stage in the evolutionary history of this pollen group.

*Distribution.*

*Lignites:* Moorlands, Beenak.

*Mudstones:* Vegetable Creek.

TABLE 7.

Locality.			Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.	
Vegetable Creek	..	..	34.5-58.5 $\mu$	45.5 $\mu$	4-6	51%	5
Beenak	..	..	32.0-50.5 $\mu$	40.0 $\mu$	5-7	54%	6

*Nothofagus* sp. *h.* (Plate ii, figs. 33-35. Text-fig. 9. Table 8).

*General remarks.*—This type has been observed in samples from only two localities. The following description is based, mainly, upon pollens obtained from the mudstones of the Balcombe Bay leaf-bed, in which it is particularly abundant.

*Grain.*—Rather flattened, somewhat angular in polar view. Size-range from 26.6-48.0 $\mu$ , the average being about 35 $\mu$ . Pores 6-9, mainly 7 and 8, majority 7, sunken approximately 5 $\mu$ .

*Exine.*—Thin but firm, about 1 $\mu$ , forming narrow rims to the pores. Sculpture fine, moderately dense, papillae short, pointed, coarser and closer at the poles.

*Affinity.*—As previously mentioned, 6- and 7-pored examples of *N. sp. h.* are often difficult to distinguish from grains of *N. sp. e.* with the same number of pores. The occurrence, in a sample, of thin-walled grains with decided pores in which the numbers 7 and 8 predominate would suggest the presence of *N. sp. h.* Such characters as shallower pores, less angular shape and slightly coarser sculpture could then be used to separate doubtful examples and confirm the identification of *N. sp. h.*

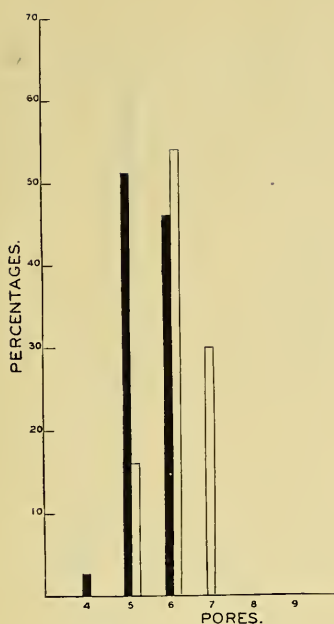
*Distribution.*

*Lignites:* Moorlands.

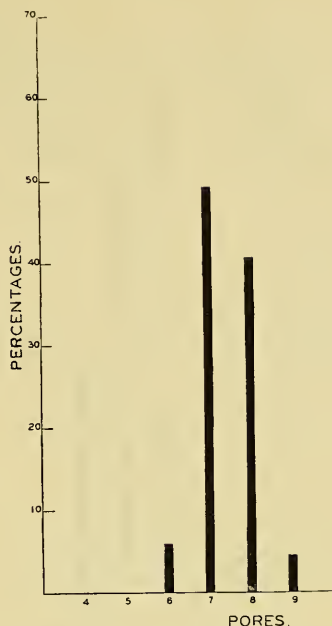
*Mudstones:* Balcombe Bay.

TABLE 8.

Locality.			Size-Range.	Average Size.	Pore-Range.	Pore-Maximum.	
Balcombe Bay	..	..	29.0-48.0 $\mu$	36 $\mu$	6-9	49%	7
Moorlands	..	..	26.6-42.5 $\mu$	34 $\mu$	6-9	58%	7



Text-fig. 8.

Text-fig. 8.—Pore-frequencies in *N. sp. g.* ■ Vegetable Creek; □ Beenak.

Text-fig. 9.

Text-fig. 9.—Pore-frequencies in *N. sp. h.* from Balcombe Bay.*Nothofagus sp. i.* (Plate ii, figs. 36-38. Text-fig. 10).

*General remarks.*—Type locality Moorlands; so far not observed in preparations from other deposits.

*Grain.*—Bi-convex, slightly angular in polar view. Size-range  $26.6\text{--}47.5\mu$ , average  $36\mu$ . Pores 6-9, majority 7, sunken about  $2.5\mu$ .

*Exine.*—Firm, about  $2\mu$ , forming short rims of the same thickness around the pores. Sculpture medium, clear; papillae pointed, but so extremely short that the exine when viewed in optical section appears smooth.

*Affinity.*—Although at present *N. sp. i.* appears to be an uncommon type, its characteristics seem sufficiently defined to warrant specific distinction. Its most striking feature is the shallow position of the pores, a feature it shares with members of the *fusca* group and *N. sp. d.* Approach to the former is made also through the clear but abbreviated papillae.

It is possible that *N. sp. i.* represents a stage in the evolution of the *N. fusca* pollen-type; the absence of especially thickened pore-rims and the pointed nature of the short papillae being distinguishing and perhaps primitive characters.

*Distribution.*

*Lignite:* Moorlands.

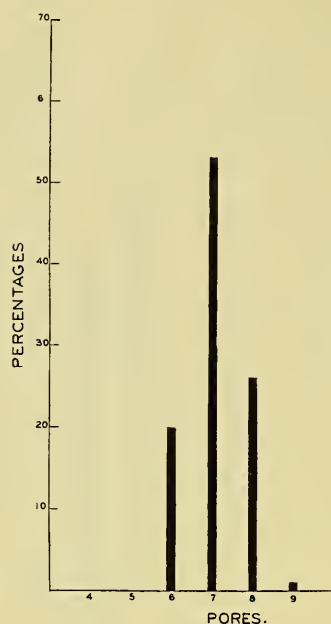
*Nothofagus sp. j.* (Plate ii, figs. 39-45. Text-fig. 11).

*General remarks.*—One of the more uncommon varieties, characterized by a heavy echinate sculpture.

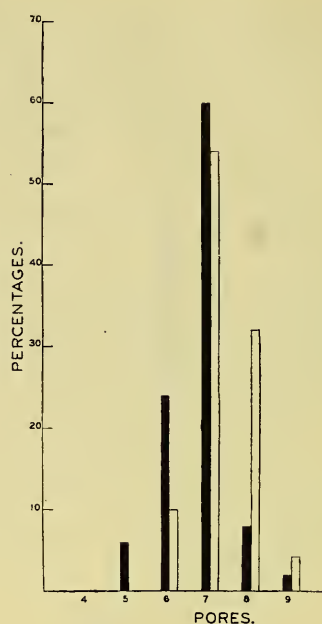
*Grain.*—Flattened, in polar view strongly angular. Size-range  $26.6\text{--}40.0\mu$ , average about  $34\mu$ . Pores 5-9, majority 7, the relative frequencies of 6 and 8 pores varying in preparations from different deposits (Text-fig. 11); sunken to a depth of from  $4\text{--}5\mu$ .

*Exine.*—Firm, approximately  $1.50\text{--}1.75\mu$ , forming decided but unthickened rims to the pore slits. Sculpture strongly developed; papillae crowded, coarse, always larger at the poles, basal diameter up to  $2.5\mu$ , length from  $1.0\text{--}2.5\mu$ , usually terminating in a sharp point but sometimes appearing as blunt, irregular tubercles.





Text-fig. 10.

Text-fig. 10.—Pore-frequencies in *N. sp. i.* from Moorlands.

Text-fig. 11.

Text-fig. 11.—Pore-frequencies in *N. sp. j.* □ Altona; ■ Budgere.

*Affinity.*—*N. sp. j.* is clearly separated from the pollens described above by the characteristic prominence of the sculpture. In general form, size, and pore-number it comes nearest to *N. sp. h.* Since it has been observed in sufficient numbers for statistical purposes from only two deposits, however, any further discussion of affinity to other species is postponed until more information concerning these extinct types as a whole is available.

#### *Distribution.*

*Lignites:* Moorlands, Altona, Beenak, Budgere.

*Mudstones:* Balcombe Bay.

#### KEY TO THE SPECIES.

A.	Grain opening by fissures .. .. .	<i>N. sp. a.</i>
	Grain with functional pores .. .. .	B
B.	Pores not deeply sunken .. .. .	C
	Pores deeply sunken .. .. .	F
C.	Exine of even thickness .. .. .	<i>N. sp. i.</i>
	Exine thicker around pores .. .. .	D
D.	Grain large, average size exceeding 35 $\mu$ .. .. .	<i>N. sp. c.</i>
	Grain small, average size less than 35 $\mu$ .. .. .	E
E.	Papillae short .. .. .	<i>N. sp. b.</i>
	Papillae prominent, echinate .. .. .	<i>N. sp. d.</i>
F.	Exine delicate, average size 40 $\mu$ or more .. .. .	<i>N. sp. g.</i>
	Exine firm, average size less than 40 $\mu$ .. .. .	G
G.	Pore-maximum 6 .. .. .	H
	Pore-maximum 7 .. .. .	I
H.	Papillae close, exine approximately 1 $\mu$ .. .. .	<i>N. sp. e.</i>
	Papillae scattered, exine approximately 2 $\mu$ .. .. .	<i>N. sp. f.</i>
I.	Sculpture fine .. .. .	<i>N. sp. h.</i>
	Sculpture coarse .. .. .	<i>N. sp. j.</i>

## SUMMARY.

The present analytical investigation supports the conclusion, drawn by previous workers from macroscopical studies of leaf-remains, that southern beeches were specifically more numerous in Australia during the Tertiary Period than at the present time. Previously von Ettingshausen (1888) distinguished six species of *Nothofagus* from beds in New South Wales and one from Tasmania, while Deane (1902) added two Victorian species to the number.

This study shows that an even greater variety of forms existed. Ten distinct pollen-types are figured and described, and there is some evidence that later more may be distinguished.

The distribution of fossil *Nothofagus* spp. as recorded by other investigators (Chapman, 1937; Deane, 1902; von Ettingshausen, 1888) is confirmed. By means of their pollens, they have been traced from South Australia to northern New South Wales, but no decision has been reached regarding the northward extension of the genus into Queensland during Oligocene-Miocene times. *N. Moorei* has a restricted distribution there to-day but lignite from Water Park Creek near Rockhampton has failed as yet to yield beech pollens.

An early date, possibly pre-Middle-Miocene, has been established for the definition of the two pollen-groups characteristic of *Nothofagus*. *N. sp. a.* is an undoubted example of the *Menziesii* type whereas *N. spp. b.* and *c.* are as clearly members of the *fusca* group.

In addition to, and associated in deposits with these, are types that cannot be so placed. They are pollens of presumably more primitive extinct species some of which may even represent stages in the evolution of more modern forms.

Statistics obtained from pore-counts (Text-figs. 2-11) support the suggestions of other workers (Cranwell, 1939, p. 191; von Post, 1929) that pore-frequency when considered in conjunction with other diagnostic features has a definite value in the separation of *Nothofagus* pollens. Of the pollens discussed here three are mainly 5- and 6-pored, while in the remaining seven species the prevailing pore-number is 7. This predominance of 7-pored pollens in the fossil as well as in the living species brings the Australian forms into line with New Zealand species where also 7-pored pollens are in the majority. The South American species of the *fusca* group (Cranwell, l.c., p. 189), on the contrary, have low pore-numbers in which 5 and 6 are by far the most numerous.

Finally it has been demonstrated that the sculpture of the exine is more pronounced in the fossil pollens than it is in those of the living species. The papillae in the former are usually clearly defined and more or less strongly echinate.

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## EXPLANATION OF PLATES I-II.

All the figures are from untouched negatives. All represent polar views of pollens of *Nothofagus* spp. at a magnification of 625 diameters.

## Plate i.

- Fig. 1.—*Nothofagus Menziesii*. A partially ruptured grain showing 7 fissure-points.
- Fig. 2.—*N. Cunninghamii*. An acetolysed grain showing one fissure and positions of 6 fissure-points. Otway Forest, Victoria.
- Fig. 3.—*N. Cunninghamii*. Grain with 2 widely open fissures. Otway Forest, Victoria.
- Fig. 4.—*N. Moorei*. Grain showing 8 fissures. Near headwaters of the Manning River, New South Wales.
- Fig. 5.—*N. sp. a*. Grain showing 8 fissure-points. Vegetable Creek, New South Wales.
- Fig. 6.—*N. sp. a*. A partially ruptured grain with 7 fissure-points. Vegetable Creek, New South Wales.
- Fig. 7.—*N. sp. a*. A large completely ruptured grain showing 8 deep fissures. Bore 155, 552 feet, Maryvale, Victoria.
- Fig. 8.—*N. sp. b*. A 7-pored grain. Bore 155, 552 feet, Maryvale, Victoria.
- Fig. 9.—*N. sp. b*. A 7-pored grain. Anglesea, Victoria.
- Fig. 10.—*N. sp. b*. A 6-pored grain. Moorlands, South Australia.
- Figs. 11, 12.—*N. sp. b*. 6-pored pollens showing coarse sculpture. Vegetable Creek, New South Wales.
- Fig. 13.—*N. sp. b*. Grain focussed to show sculpture. Moorlands, South Australia.
- Figs. 14, 15.—*N. Gunnii*. Acetolysed grains. Cradle Mountain, Tasmania.
- Fig. 16.—*N. fusca*. Acetolysed grain focussed for sculpture. Eglington Valley, New Zealand.
- Fig. 17.—*N. sp. c*. Large 7-pored grain. Bore 155, 552 feet, Maryvale, Victoria.
- Fig. 18.—*N. sp. c*. 6-pored grain, Lal Lal, Victoria.
- Fig. 19.—*N. sp. d*. 6-pored grain. Yallourn, S.E.C., sample 6, 150 feet from top of coal.
- Fig. 20.—*N. sp. d*. 6-pored grain. Budgerie, Victoria.
- Fig. 21.—*N. sp. d*. 7-pored grain. Yallourn, S.E.C., sample 6.

## Plate ii.

- Fig. 22.—*N. sp. e*. 6-pored grain with closed pore-slits. Bore 155, 552 feet, Maryvale, Victoria.
- Figs. 23, 24.—*N. sp. e*. 6- and 7-pored grains with partially open pore-slits. Kiandra, New South Wales.
- Fig. 25.—*N. sp. e*. 5-pored grain with widely open pore-slits. Yallourn, S.E.C. sample 4, 92 feet below top of coal.
- Figs. 26, 27.—*N. sp. f*. 5- and 6-pored grains. Boolara, Victoria.
- Fig. 28.—*N. sp. f*. 6-pored grain focussed for sculpture. Boolara, Victoria.
- Fig. 29.—*N. sp. f*. 6-pored grain. Moorlands, South Australia.



- Fig. 30.—*N. sp. g.* 5-pored grain. Vegetable Creek, New South Wales.  
Fig. 31.—*N. sp. g.* 6-pored grain. Moorlands, South Australia.  
Fig. 32.—*N. sp. g.* 7-pored grain. Beenak, Victoria.  
Figs. 33-35.—*N. sp. h.* 7-, 8-, 9-pored grains. Balcombe Bay, Victoria.  
Figs. 36-38.—*N. sp. i.* 7- and 8-pored grains. Moorlands, South Australia.  
Fig. 39.—*N. sp. j.* 5-pored grain. Budgerie, Victoria.  
Fig. 40.—*N. sp. j.* Grain with partially open pore-slits. Altona, Victoria.  
Fig. 41.—*N. sp. j.* 6-pored grain with open pore-slits. Altona, Victoria.  
Fig. 42.—*N. sp. j.* 7-pored grain. Balcombe Bay, Victoria.  
Fig. 43.—*N. sp. j.* 7-pored grain. Budgerie, Victoria.  
Fig. 44.—*N. sp. j.* 7-pored grain showing papillae in relief. Beenak, Victoria.  
Fig. 45.—*N. sp. j.* 8-pored grain. Moorlands, South Australia.
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